US007347045B2

(12) United States Patent
Bozmoski et al.

(10) Patent No.: US 7,347,045 B2
(45) Date of Patent: Mar. 25, 2008

(54) **MOTORCYCLE DYNAMIC EXHAUST SYSTEM**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 368 days.

(21) Appl. No.: **10/881,189**

(22) Filed: **Jun. 30, 2004**

(65) **Prior Publication Data**

US 2006/0000205 A1 Jan. 5, 2006

(51) **Int. Cl.**
F02B 27/02 (2006.01)

(52) **U.S. Cl.** **60/312**; 60/287; 60/324

(58) **Field of Classification Search** 60/287, 60/288, 312, 324

See application file for complete search history.

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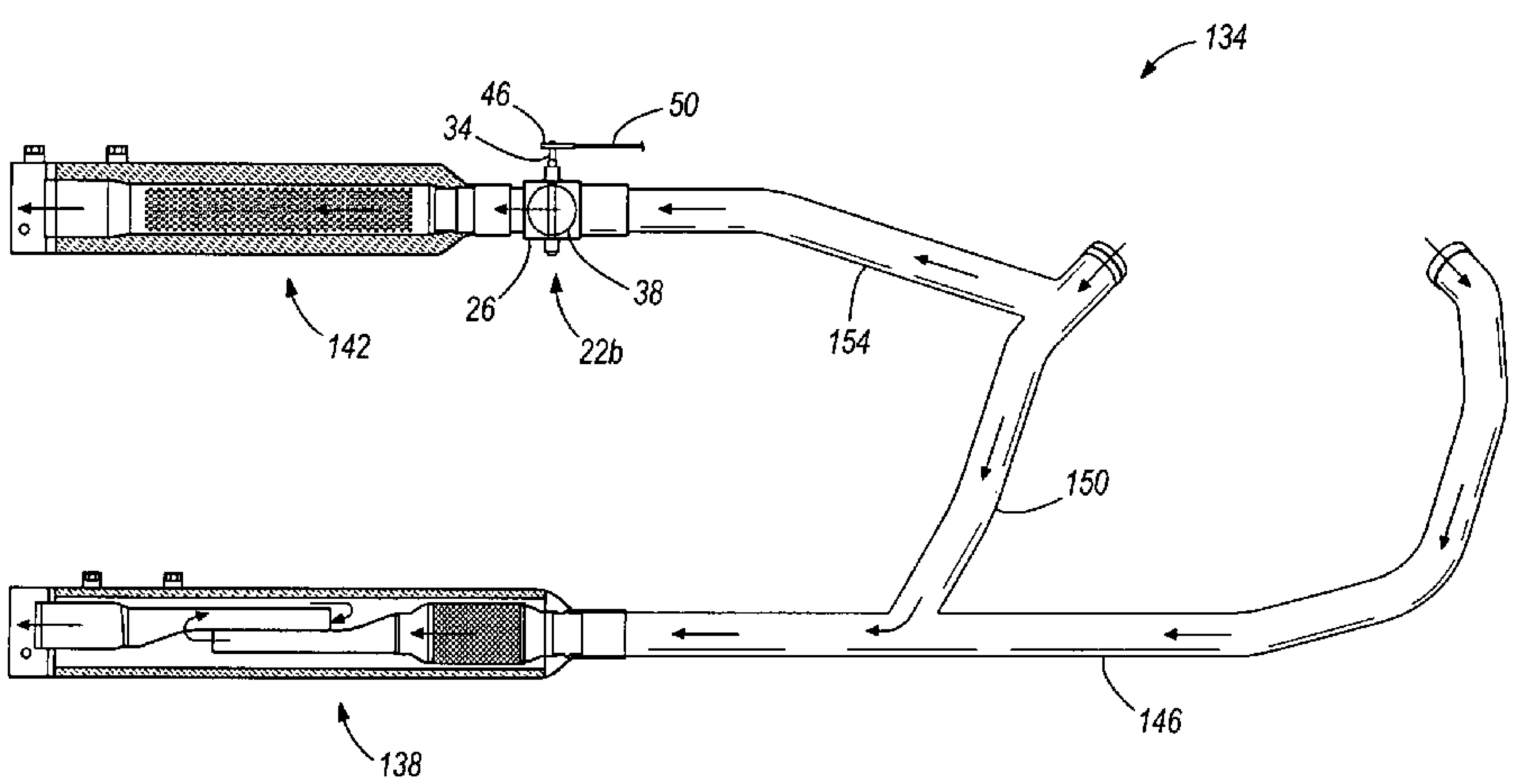
(57) **ABSTRACT**

The present invention provides a method of operating a dynamic exhaust system of a motorcycle engine. The method includes providing a valve in the exhaust system that is movable to direct exhaust gases between a first flow path through the exhaust system and a second flow path through the exhaust system. The method includes actuating the valve at a first speed to redirect exhaust gases from the first flow path to the second flow path and actuating the valve at a second speed greater than the first speed to redirect exhaust gases from the second flow path to the first flow path.

10 Claims, 7 Drawing Sheets



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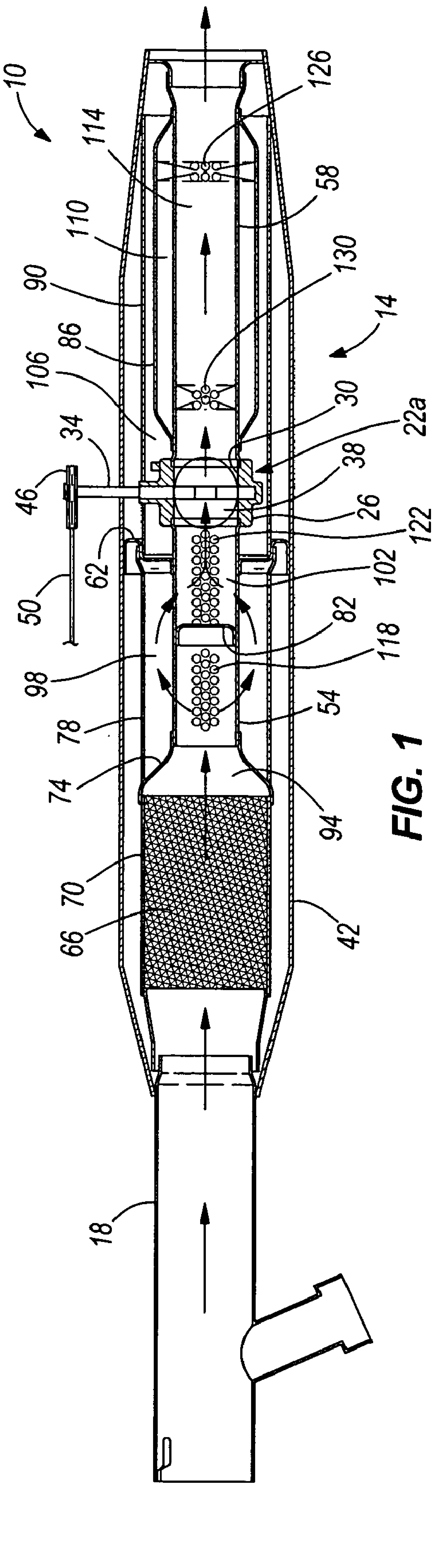
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22a
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FIG. 1

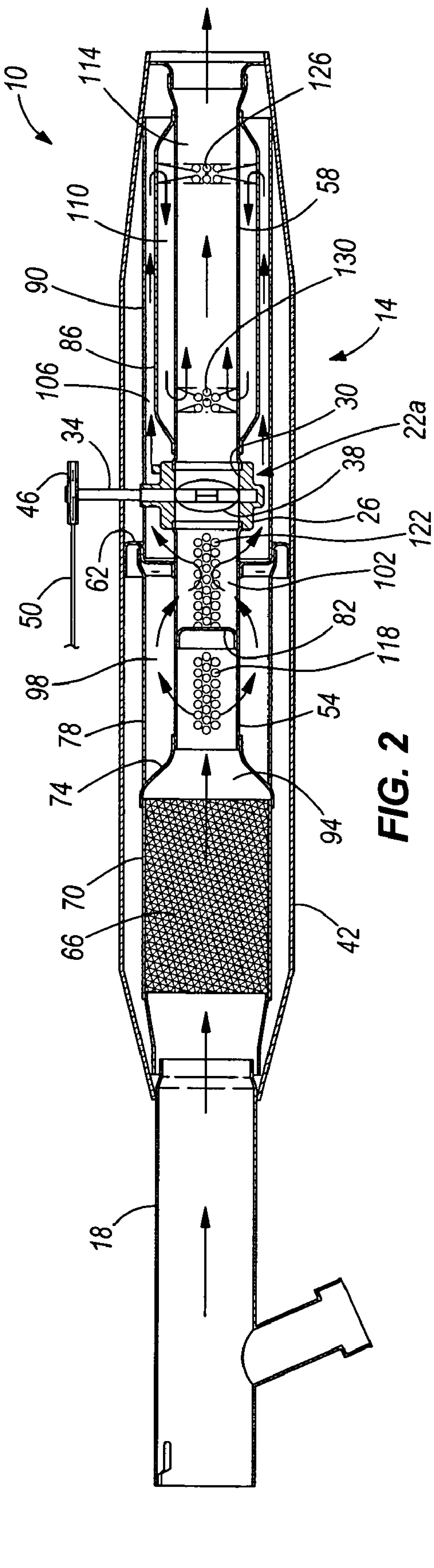
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FIG. 2

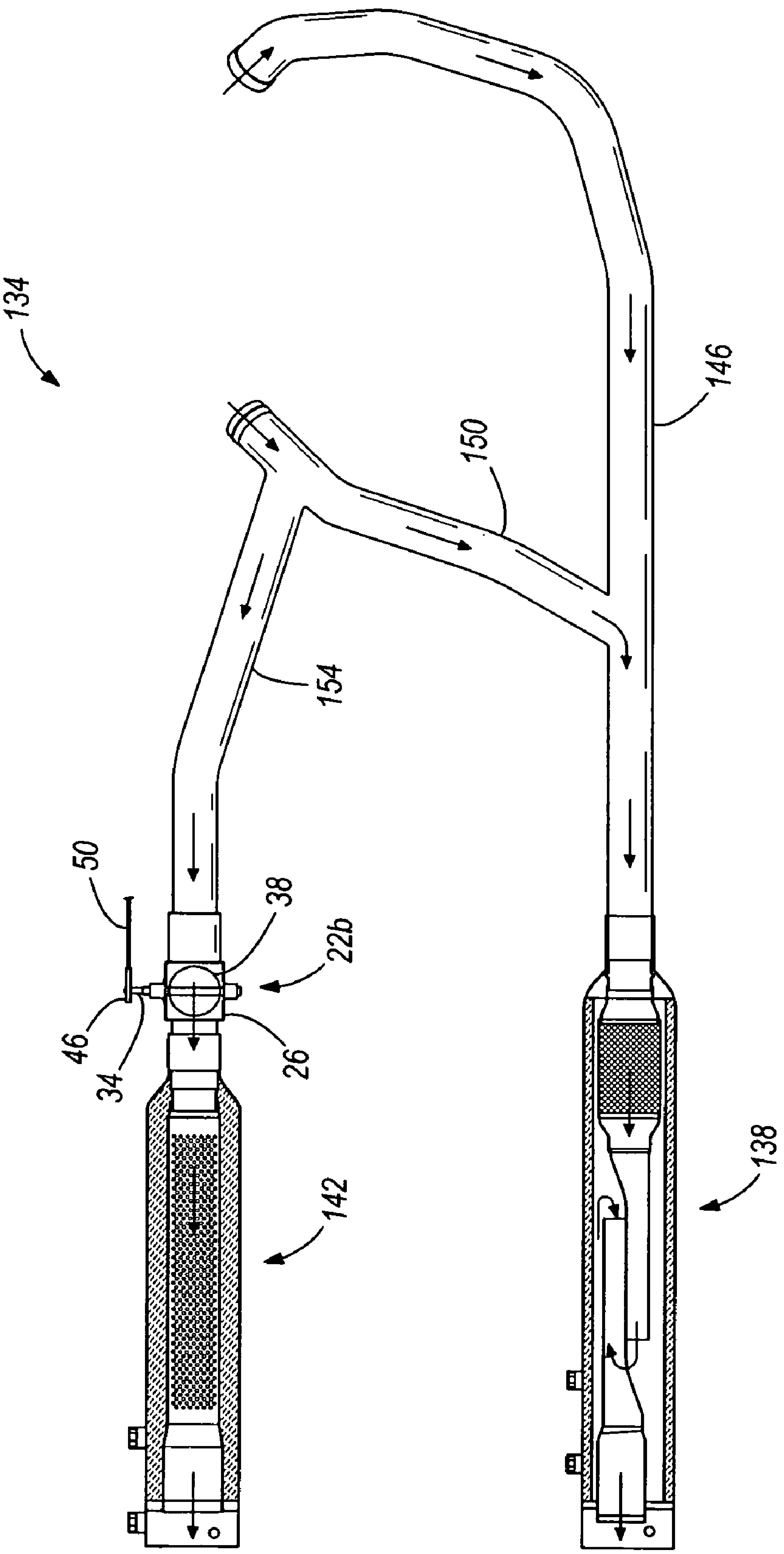

FIG. 3

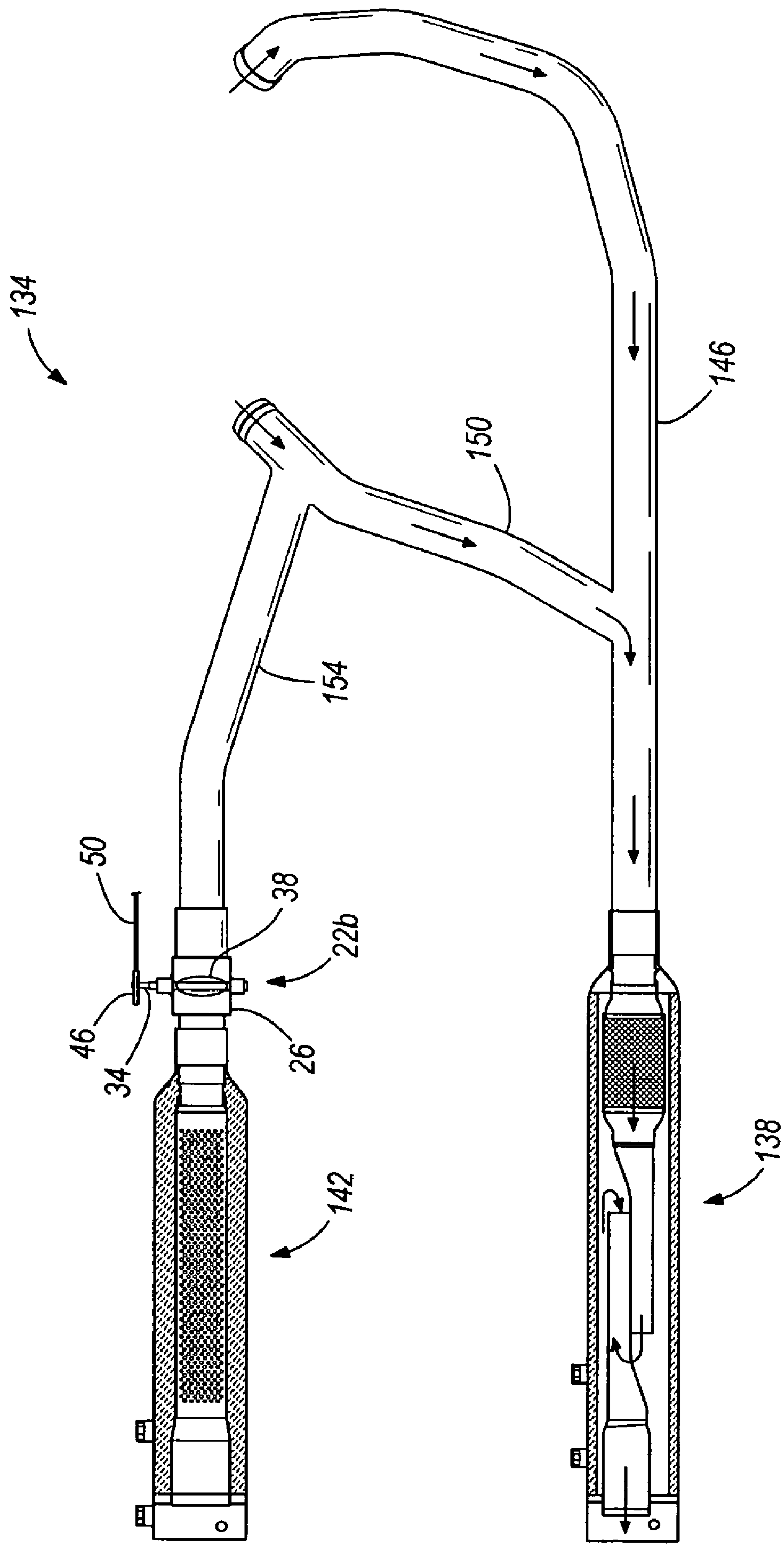

FIG. 4

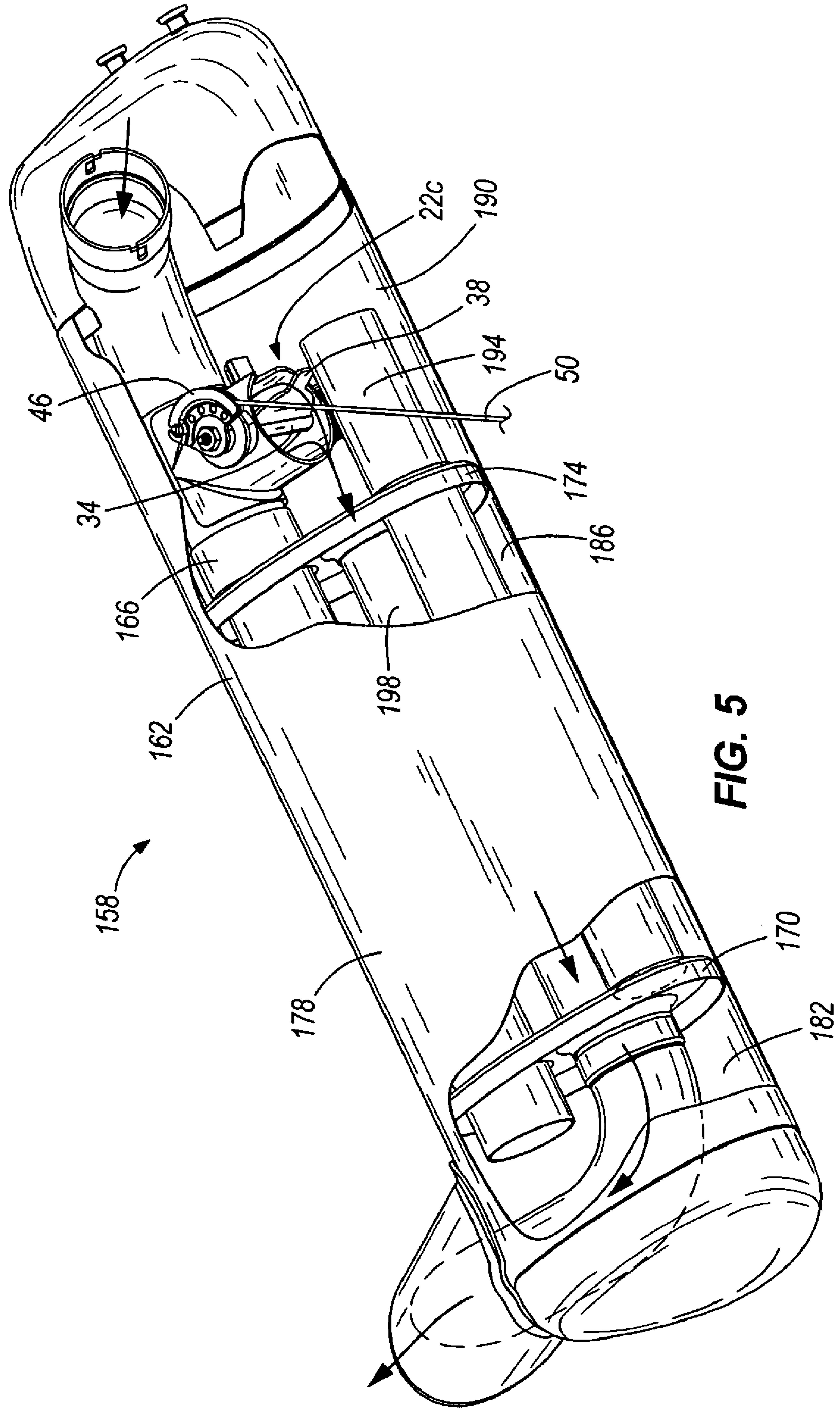

FIG. 5

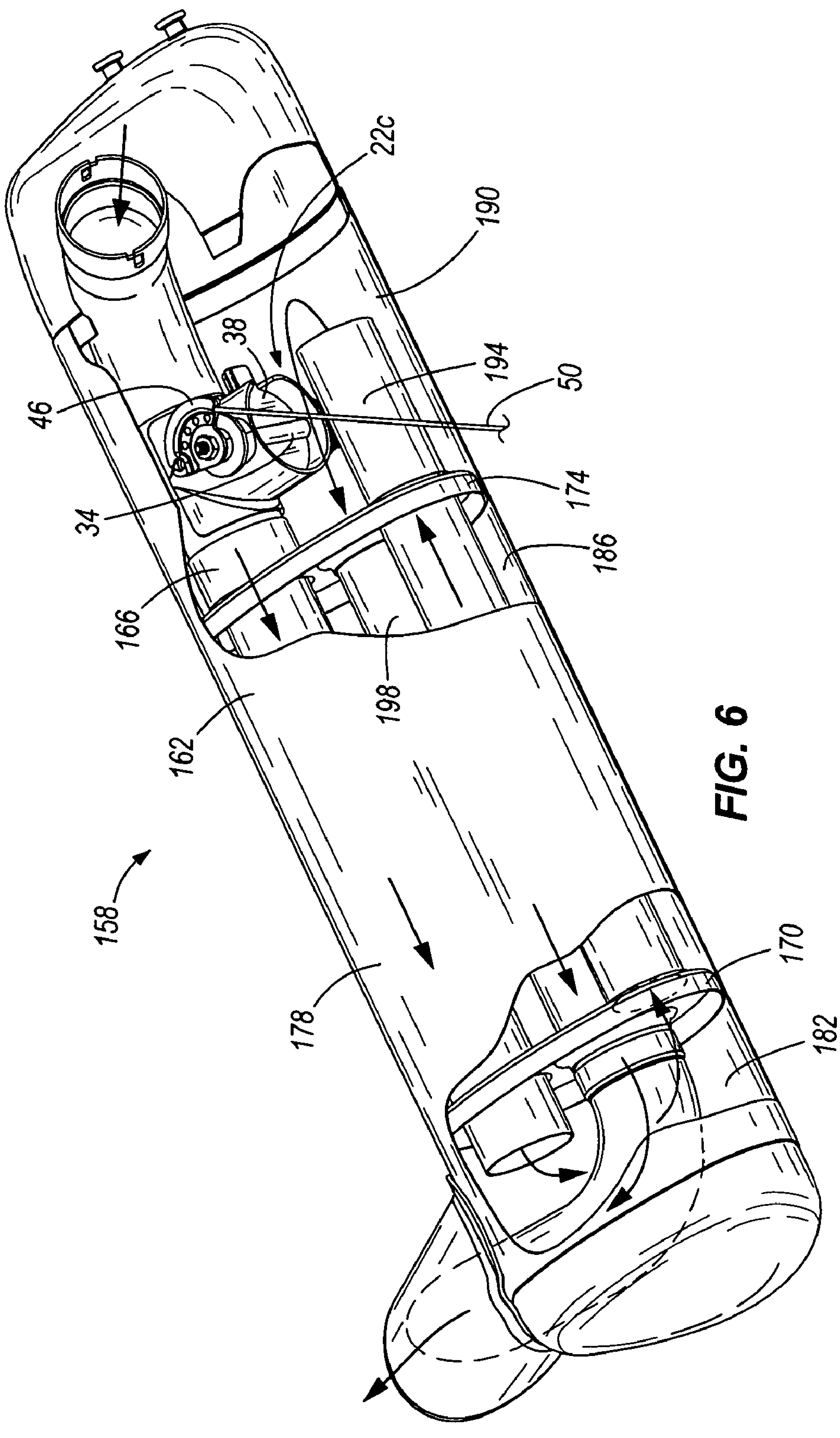

FIG. 6

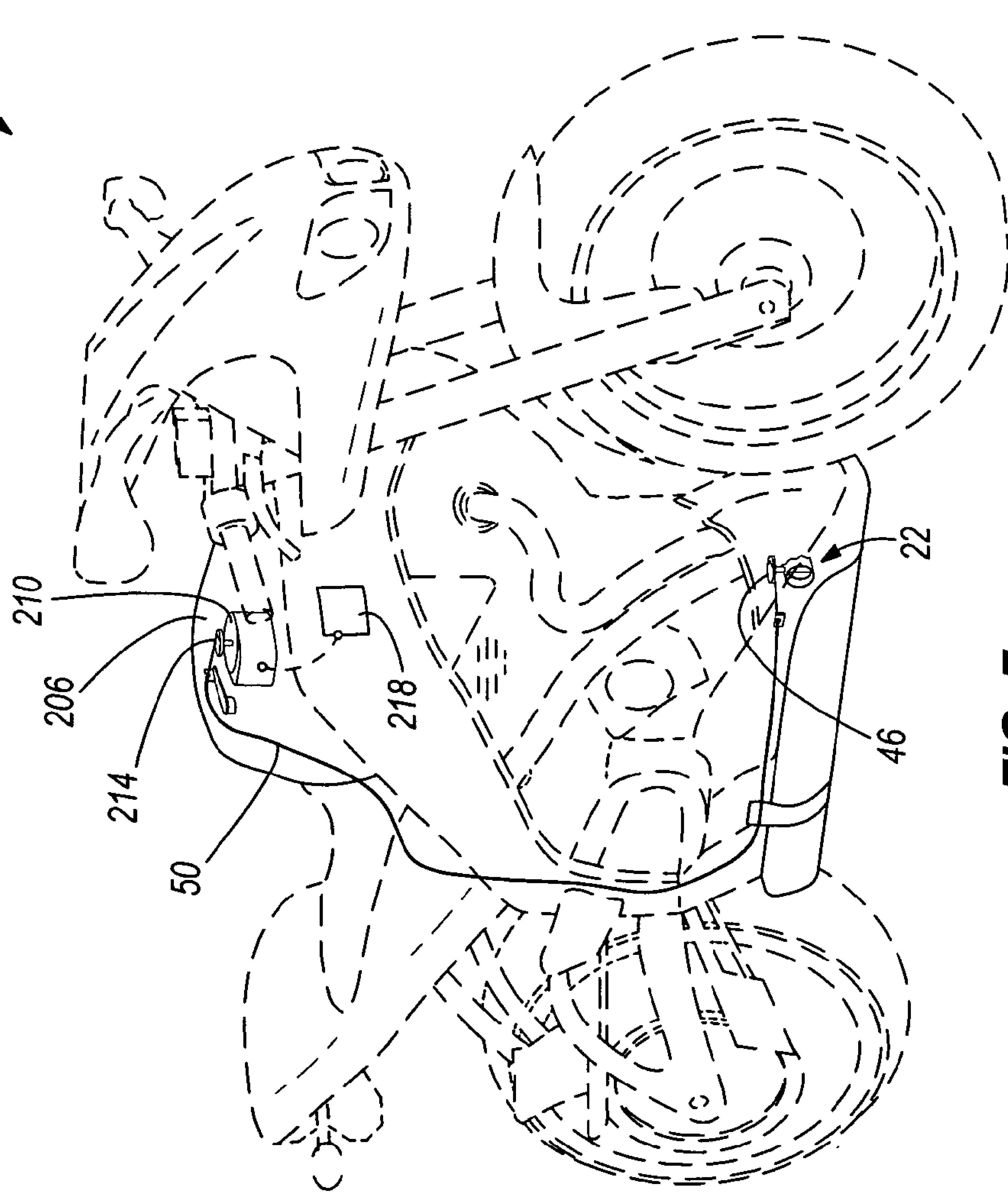

FIG. 7

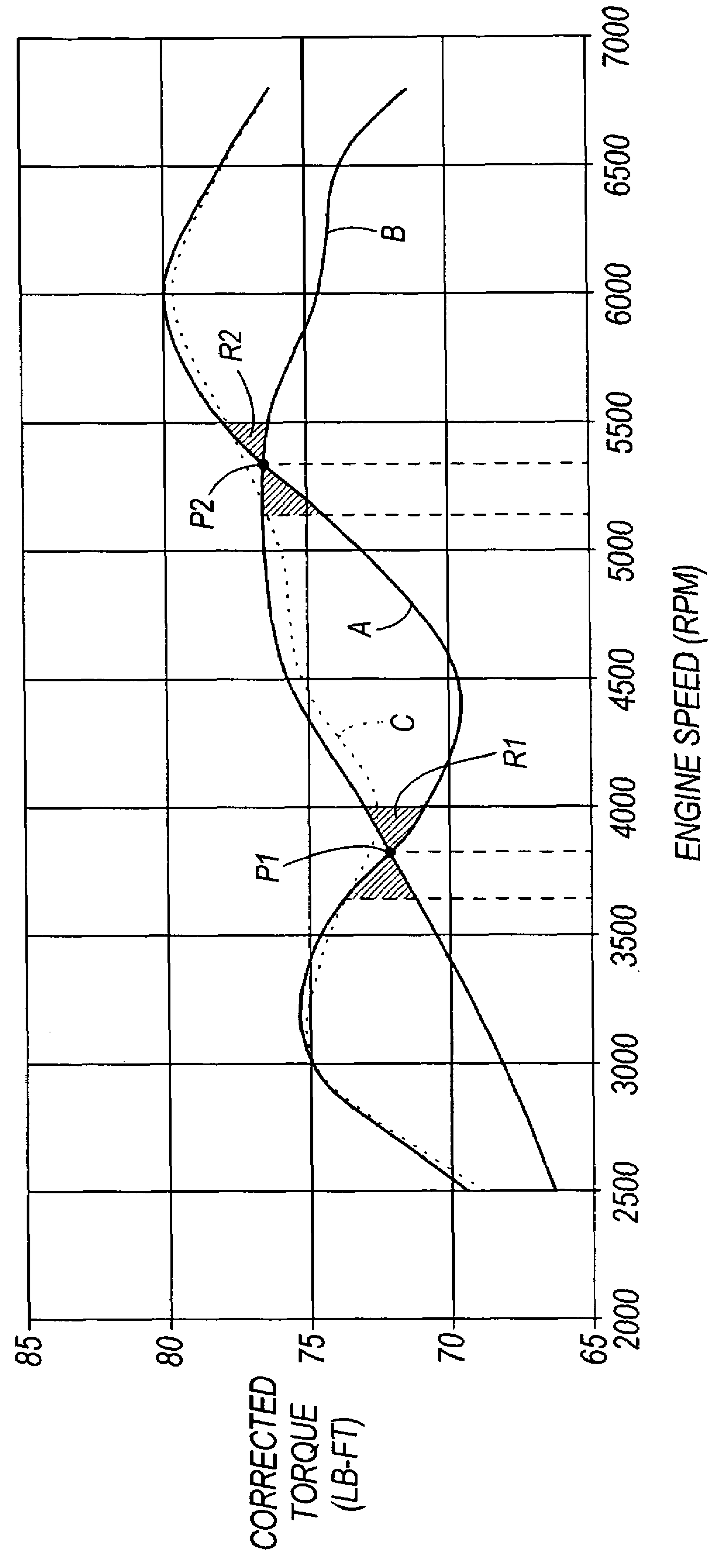
CORRECTED TORQUE (LB-FT)
85
80
75
70
65
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
ENGINE SPEED (RPM)
A
B
C
P1
P2
R1
R2

FIG. 8

MOTORCYCLE DYNAMIC EXHAUST SYSTEM

FIELD OF THE INVENTION

This invention relates generally to motorcycles, and more particularly to dynamic exhaust systems for motorcycles.

BACKGROUND OF THE INVENTION

Various designs of motorcycle dynamic exhaust systems are known in the art. Typically, dynamic exhaust systems are utilized to alter the performance of the motorcycle's engine and/or the noise emissions from the motorcycle's engine. In a conventional dynamic exhaust system for a motorcycle, a valve is positioned in a muffler to define a restrictive flow path through the muffler, which may be utilized when it is desirable to decrease the noise emissions of the engine, and a less restrictive flow path, which may be utilized when it is desirable to increase the performance of the engine. The valve is typically moved to direct exhaust gases from the engine through either of the restrictive or less restrictive flow paths. An actuator that is responsive to engine vacuum is commonly utilized to actuate the valve, such that when engine vacuum is high, the actuator actuates the valve to direct the exhaust gases through the restrictive flow path of the muffler to quiet the engine. Also, when the engine vacuum is low, the actuator actuates the valve to direct the exhaust gases through the less restrictive flow path of the muffler to increase the performance of the engine.

SUMMARY OF THE INVENTION

The present invention provides a method of operating an dynamic exhaust system of a motorcycle engine. The method includes providing a valve in the exhaust system that is movable to direct exhaust gases between a first flow path through the exhaust system and a second flow path through the exhaust system. The method includes actuating the valve at a first speed to redirect exhaust gases from the first flow path to the second flow path and actuating the valve at a second speed greater than the first speed to redirect exhaust gases from the second flow path to the first flow path.

The method includes, in another aspect, actuating the valve in the exhaust system in a crossover region of first and second torque characteristics of the first and second flow paths, respectively.

The present invention provides, in yet another aspect, a motorcycle including a valve and an actuator supported by an airbox. The actuator is operatively coupled to the valve to move the valve between a first position, in which exhaust gases are directed along the first flow path, and a second position, in which exhaust gases are directed along the second flow path.

Other features and aspects of the present invention will become apparent to those skilled in the art upon review of the following detailed description, claims and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, wherein like reference numerals indicate like parts:

FIG. **1** is a cross-sectional view of a first construction of a dynamic exhaust system embodying the present invention, illustrating exhaust gases flowing through a first flow path of the exhaust system.

FIG. **2** is a cross-sectional view of the dynamic exhaust system of FIG. **1**, illustrating exhaust gases flowing through a second flow path of the exhaust system.

FIG. **3** is a partial cross-sectional view of a second construction of a dynamic exhaust system embodying the present invention, illustrating exhaust gases flowing through a first flow path of the exhaust system.

FIG. **4** is a partial cross-sectional view of the dynamic exhaust system of FIG. **3**, illustrating exhaust gases flowing through a second flow path of the exhaust system.

FIG. **5** is a cutaway perspective view of a third construction of a dynamic exhaust system embodying the present invention, illustrating exhaust gases flowing through a first flow path of the exhaust system.

FIG. **6** is a cutaway perspective view of the dynamic exhaust system of FIG. **5**, illustrating exhaust gases flowing through a second flow path of the exhaust system.

FIG. **7** is a perspective view of a motorcycle including the dynamic exhaust system of FIGS. **5** and **6**, illustrating an actuator positioned remotely from the exhaust system.

FIG. **8** is a graph illustrating a first torque characteristic of a motorcycle engine representative of exhaust gases flowing through the first flow path of the exhaust system of FIGS. **5** and **6**, and a second torque characteristic of the motorcycle engine representative of exhaust gases flowing through the second flow path of the exhaust system of FIGS. **5** and **6**.

Before any features of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced or being carried out in various ways. Also, it is understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including", "having", and "comprising" and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. The use of letters to identify elements of a method or process is simply for identification and is not meant to indicate that the elements should be performed in a particular order.

DETAILED DESCRIPTION

FIGS. **1** and **2** illustrate a first construction of a motorcycle dynamic exhaust system **10** embodying the present invention. The exhaust system **10** includes a muffler **14** coupled to an exhaust pipe **18** in a conventional manner. Although not shown, the exhaust system **10** may incorporate a second exhaust pipe and a second muffler.

The muffler **14** incorporates a valve assembly **22**_a_ to direct the flow of exhaust gases through the muffler **14**. In the illustrated construction, the valve assembly **22**_a_ includes a valve housing **26** defining a central passageway **30**. A shaft **34** is rotatably supported by the valve housing **26**, and a butterfly valve **38** is coupled to the shaft **34**. The butterfly valve **38** is positioned in the central passageway **30** to selectively restrict the flow of exhaust gases through the passageway **30**, as discussed in more detail below. The shaft **34** extends through an outer shell **42** of the muffler **14**, and a quadrant or a lever **46** is coupled to the shaft **34** to receive a cable **50** for pivoting or rotating the shaft **34** and the butterfly valve **38**.

The muffler **14** also includes an inlet tube **54** coupled to the valve housing **26** at an inlet end of the valve housing **26**, and an outlet tube **58** coupled to the valve housing **26** at an outlet end of the valve housing **26**. The inlet tube **54** is supported in the outer shell **42** of the muffler **14** by a tube support member **62**. The muffler **14** further includes a catalyst **66** located within a catalyst tube **70**, which is coupled to the inlet tube **54** via a transition sleeve **74**. A first sleeve **78** surrounds the inlet tube **54** and is coupled between the tube support member **62** and the transition sleeve **74**. A plug **82** is positioned within the inlet tube **54** such that unobstructed flow of exhaust gases through the entire length of the inlet tube **54** is restricted.

With continued reference to FIGS. **1** and **2**, the muffler **14** includes a second sleeve **86** surrounding the outlet tube **58**, such that opposite ends of the second sleeve **86** are pinched into contact with the outer surface of the outlet tube **58**. The muffler **14** also includes a third sleeve **90** surrounding the second sleeve **86**, with one end of the third sleeve **90** being coupled to the tube support member **62** and the opposite end being in abutting contact with the outer shell **42**.

As a result of the above-identified internal components of the muffler **14**, the muffler **14** generally defines a plurality of chambers through which exhaust gases may flow. More particularly, the space bounded by the catalyst tube **70**, the transition sleeve **74**, and a portion of the inlet tube **54** upstream of the plug **82** defines a first chamber **94**, while the space bounded by the first sleeve **78**, the inlet tube **54**, the transition sleeve **74**, and the tube support member **62** defines a second chamber **98**. In addition, the space bounded by a portion of the inlet tube **54** downstream of the plug **82** and the closed butterfly valve **38** defines a third chamber **102**, and the space bounded between the second sleeve **86**, the third sleeve **90**, and the tube support member **62** defines a fourth chamber **106**. Further, the space bounded by the second sleeve **86** and the outlet tube **58** defines a fifth chamber **110**, while the space bounded by the closed butterfly valve **38** and the outlet tube **58** defines a sixth chamber **114**.

With reference to FIG. **1**, a first flow path of exhaust gases is shown through the muffler **14** by a sequence of arrows. The butterfly valve **38** is shown pivoted to an open position, in which unobstructed flow of exhaust gases is allowed through the passageway **30** in the valve housing **26**. More particularly, exhaust gases exiting the exhaust pipe **18** enter the first chamber **94** of the muffler **14** and encounter the plug **82**, which redirects the exhaust gases into the second chamber **98** via a plurality of first apertures **118** formed in the inlet tube **54**. The exhaust gases are then directed into the third chamber **102** via a plurality of second apertures **122** formed in the inlet tube **54**. From the third chamber **102**, the exhaust gases may pass unobstructed through the passageway **30** of the valve housing **26** and enter the sixth chamber **114**, thereby bypassing the fourth and fifth chambers **106**, **110** of the muffler **14**. From the sixth chamber **114**, the exhaust gases may exit the muffler **14**.

With reference to FIG. **2**, a second flow path of exhaust gases is shown through the muffler **14** by a sequence of arrows. The butterfly valve **38** is shown pivoted to a closed position, in which exhaust gases are not allowed to flow through the passageway **30** in the valve housing **26**. More particularly, exhaust gases pass through the first, second, and third chambers **94**, **98**, **102** as described above with reference to FIG. **1**. However, since the butterfly valve **38** is closed, exhaust gases in the third chamber **102** are directed into the fourth chamber **106** via the plurality of second apertures **122**. From the fourth chamber **106**, the exhaust gases are directed into the fifth chamber **110** via a plurality of third apertures **126** formed in the second sleeve **86**. Further, the exhaust gases in the fifth chamber **110** are directed into the sixth chamber **114** via a plurality of fourth apertures **130** formed in the outlet tube **58**. From the sixth chamber **114**, the exhaust gases may exit the muffler **14**.

FIGS. **3** and **4** illustrate a second construction of a motorcycle dynamic exhaust system **134** of the present invention. The exhaust system **134** is a dual exhaust system **134** including a first muffler **138** and a second muffler **142**. In the illustrated construction, the first muffler **138** is a conventional multi-chamber muffler **138** while the second muffler **142** is a high-performance single chamber muffler **142**. However, alternate constructions of the exhaust system **134** may utilize two high-performance single chamber mufflers **142** or two conventional multi-chamber mufflers **138**.

In the illustrated construction, a valve **22*b*** is positioned in the exhaust system **134** upstream of the second muffler **142**. The valve **22*b*** is substantially similar to the valve **22*a*** shown in FIGS. **1** and **2**. As shown in FIGS. **3** and **4**, the exhaust system **134** also includes a first exhaust pipe **146** coupled to the first muffler **138**, and a second exhaust pipe **150** coupled to and merged with the first exhaust pipe **146**. The first and second exhaust pipes **146**, **150** may be connected to respective exhaust ports of a motorcycle engine (e.g., a V-twin engine, not shown) to receive exhaust gases. The exhaust system **134** further includes a third exhaust pipe **154** coupled to and merged with the second exhaust pipe **150**. The third exhaust pipe **154** is also coupled to the valve **22*b***, which, in turn, is coupled to the second muffler **142**.

With reference to FIG. **3**, a first flow path of exhaust gases is shown through the exhaust system **134** by a sequence of arrows. The butterfly valve **38** is shown pivoted to an open position, in which unobstructed flow of exhaust gases is allowed through the valve **22*b***. More particularly, exhaust gases may be redirected from the second exhaust pipe **150** to the third exhaust pipe **154**, thereby utilizing both of the first and second mufflers **138**, **142**.

With reference to FIG. **4**, a second flow path of exhaust gases is shown through the exhaust system **134** by a sequence of arrows. The butterfly valve **38** is shown pivoted to a closed position, in which exhaust gases are not allowed to flow through the valve **22*b***. More particularly, exhaust gases may not be redirected from the second exhaust pipe **150** to the second muffler **142**, thereby only utilizing the first muffler **138** in the exhaust system **134**.

FIGS. **5** and **6** illustrate a third construction of a motorcycle dynamic exhaust system **158** of the present invention. The exhaust system **158** includes a muffler **162** coupled to an exhaust pipe (not shown) in a conventional manner. Although not shown, the motorcycle may include a dual exhaust system utilizing a second exhaust pipe and a second muffler.

Like the muffler **14** of FIGS. **1** and **2**, the muffler **162** incorporates a valve **22*c*** therein to direct the flow of exhaust gases through the muffler **162**. The valve **22*c*** is substantially similar to the valve **22*a*** shown in FIGS. **1** and **2**. As shown in FIGS. **5** and **6**, the valve **22*c*** is coupled to a first or inlet tube **166** of the muffler **162**. The inlet tube **166** is supported by a first wall **170** and a second wall **174**, which divide the interior space of the muffler **162** as bounded by an outer shell **178** into a first chamber **182**, a second chamber **186**, and a third chamber **190**. The muffler **162** also includes a second or connecting tube **194** supported by the first and second walls **170**, **174** that communicates the first and third chambers **182**, **190**. Further, the muffler **162** includes a third or outlet tube **198** supported by the first and second walls **170**, **174** that communicates the third chamber **190** with the atmosphere.

With reference to FIG. **5**, a first flow path of exhaust gases is shown through the exhaust system **158** by a sequence of arrows. The butterfly valve **38** is shown pivoted to an open position, in which unobstructed flow of exhaust gases is allowed through the valve **22***c*. As such, exhaust gases from the inlet tube **166** are allowed to discharge directly into the third chamber **190** (i.e., bypassing the first chamber **182**), where the exhaust gases may flow through the outlet tube **198** and exit the muffler **162**.

With reference to FIG. **6**, a second flow path of exhaust gases is shown through the exhaust system **158** by a sequence of arrows. The butterfly valve **38** is shown pivoted to a closed position, in which exhaust gases are not allowed to flow through the valve **22***c*. As such, exhaust gases are directed to the first chamber **182** via the inlet tube **166**, and to the third chamber **190** via the connecting tube **194**. From the third chamber **190**, the exhaust gases may flow through the outlet tube **198** and exit the muffler **162**.

With reference to FIG. **7**, a motorcycle **202** is shown that incorporates the dynamic exhaust system **158** of FIGS. **5** and **6**. FIG. **7** schematically illustrates the valve **22***c* positioned toward the bottom of the motorcycle **202**. However, in a motorcycle configured to receive the exhaust systems **10**, **134**, the valves **22***a*, **22***b* may be positioned relative to the motorcycle in a location appropriate with the configuration of the respective exhaust systems **10**, **134**. As such, the position of the valve **22***c* as shown in FIG. **7** is for illustrative purposes only.

The illustrated motorcycle **202** is configured with an airbox (the location of which is designated by reference numeral **206**) in a location on the motorcycle **202** typically associated with a fuel tank. The airbox **206** houses conventional air intake components (e.g., an air filter, not shown) for the engine. The airbox **206** is also configured to receive an actuator **210** for opening and closing the valve **22***c* of the exhaust system **158**. The actuator **210** may be mounted on top of the airbox **206** and protected by a cover (not shown) covering the airbox **206**.

The actuator **210** may be a conventional servo-motor having a quadrant or lever **214** for pulling or releasing the cable **50**. The cable **50** is schematically illustrated as extending from the upper portion of the motorcycle **202** to the bottom portion of the motorcycle **202**. However, the cable **50** may extend in any direction on the motorcycle **202** depending on the location of the valve **22***c* in the exhaust system **158**. The cable **50** may also be substantially hidden from view by routing the cable **50** through frame members of the motorcycle **202** and/or hidden from view behind one or more fairings or body panels of the motorcycle **202**.

The actuator **210** is electrically connected to an engine control unit **218** ("ECU") of the motorcycle **202**. In addition to controlling other functions of the motorcycle **202** (e.g., fuel injection, engine timing, etc.), the ECU **218** is configured to control operation of the actuator **210**. In addition, a second cable may be utilized to actuate a second valve.

Any of the dynamic exhaust systems **10**, **134**, **158** of FIGS. **1**-**6** may be utilized to alter the performance of the motorcycle's engine and/or alter the noise emission characteristics of the motorcycle's engine. With reference to FIG. **8**, the engine's torque output is shown as a function of engine speed (measured in revolutions per minute, or RPM). More particularly, curve A illustrates the engine's torque output when the exhaust gases are routed through the first flow path of the exhaust system **158**, in which the valve **22***c* is opened. Likewise, curve B illustrates the engine's torque output when the exhaust gases are routed through the second flow path of the exhaust system **158**, in which the valve **22***c* is closed.

As shown in FIG. **8**, the engine's torque output may be increased by opening the valve **22***c* during low engine speeds and during high engine speeds. However, maintaining the valve **22***c* open during mid-range engine speeds may also cause a decrease in torque output compared to the engine's output when the valve **22***c* is closed. Such a decrease in torque output may be caused by reversion of the exhaust gases in the exhaust system **158**.

The engine exhibits different operating characteristics, or "torque characteristics," depending on the position (e.g., open or closed) of the valve **22***c*. For example, when the valve **22***c* is in an open position, the engine may exhibit a first torque characteristic defined by curve A. Likewise, when the valve is in a closed position, the engine may exhibit a second torque characteristic defined by curve B. Selective actuation of the valve **22***c* between open and closed positions may allow the engine to exhibit a third torque characteristic defined by curve C that takes advantage of the increase in torque output provided by the first operating characteristic during low engine speeds and high engine speeds, while also taking advantage of the torque output provided by the second operating characteristic during mid-range engine speeds to reduce the effects of the above-described reversion phenomena.

More particularly, for the engine to exhibit the third torque characteristic and follow curve C, the valve **22***c* is selectively controlled according to engine speed to cause the engine to switch or transition between exhibiting the first torque characteristic and exhibiting the second torque characteristic. For example, the valve **22***c* may be actuated from an open position to a closed position in a first crossover region, designated R**1** in FIG. **8**. The first crossover region R**1** may be centered about a first intersection or crossover point (designated P**1**) of curve A and curve B. Crossover point P**1** correlates with the engine speed at which the engine outputs substantially the same amount of torque whether it is exhibiting the first torque characteristic or the second torque characteristic. As shown in FIG. **8**, crossover point P**1** occurs at about 3800 RPM, and the crossover region R**1** may extend between about 3600 RPM and about 4000 RPM. However, differently-configured engines may exhibit different torque characteristics than those defined by curve A and curve B. As such, crossover point P**1** may occur at a higher or a lower engine speed than 3800 RPM, and the crossover region R**1** may be wider (i.e., encompass a greater range of engine speeds) or more narrow (i.e., encompass a smaller range of engine speeds) than that illustrated in FIG. **8**.

For the engine to continue exhibiting the third torque characteristic and following curve C, the valve **22***c* is actuated from the closed position back to the open position in a second crossover region, designated R**2** in FIG. **8**. The second crossover region R**2** may be centered about a second intersection or crossover point (designated P**2**) of curve A and curve B. As shown in FIG. **8**, crossover point P**2** occurs at about 5300 RPM, and the crossover region R**2** may extend between about 5100 RPM and about 5500 RPM. However, differently-configured engines may exhibit different torque characteristics than those defined by curve A and curve B. As such, crossover point P**2** may occur at a higher or a lower engine speed than 5100 RPM, and the crossover region R**2** may be wider (i.e., encompass a greater range of engine speeds) or more narrow (i.e., encompass a smaller range of engine speeds) than that illustrated in FIG. **8**.

More particularly, the ECU **218** may be configured to trigger the actuator **210**, which in turn may actuate the valve **22***c*, when the engine speed reaches the crossover points P**1**, P**2** in the respective crossover regions R**1**, R**2**. However, with respect to the crossover region R**1**, the ECU **218** may trigger the actuator **210** at an engine speed within the crossover region R**1** but at a lower speed or a higher speed than the crossover point P**1**. Likewise, with respect to the crossover region R**2**, the ECU **218** may trigger the actuator **210** at an engine speed within the crossover region R**2** but at a lower speed or a higher speed than the crossover point P**2**.

The ECU **218** may also trigger the actuator **210** slightly before the engine speed reaches the crossover point P**1**, or slightly before the engine speed reaches the crossover point P**2** to take into account the mechanical lag associated with the actuator **210**, cable **50**, and valve **22***c*. In addition, the ECU **218** may be configured to automatically make slight corrections to the engine speed when the valve **22***c* is actuated based upon input received by the ECU **218** from various engine or motorcycle sensors. Further, one or more conditions may need to be satisfied in order for the ECU **218** to trigger the actuator **210**. For example, a condition that the engine must be operating at 75% of full throttle or more may need to be satisfied in order for the ECU **218** to trigger the actuator **210**.

The ECU **218** may also be configured to trigger the actuator **210**, and thus the valve **22***c*, according to the speed of the motorcycle **202**. It may be desirable to trigger the actuator **210** according to the speed of the motorcycle **202** to alter the noise emission characteristics of the engine. For example, it may be desirable to operate the engine below a pre-determined sound level during mid-range cruising speeds (e.g., between 10 miles per hour and 50 miles per hour, or MPH). As a result, the ECU **218** may be configured to actuate the valve **22***c* from the open position to the closed position at about 10 MPH. In the closed position, the valve **22***c* directs exhaust gases along a second flow path longer than the first flow path to provide additional muffling of the sound pulses of the exhaust gases. At about 50 MPH, the ECU **218** may be configured to actuate the valve **22***c* back to the open position from the closed position. In the open position, the valve **22***c* directs exhaust gases along the first flow path to decrease the amount of muffling of the sound pulses of the exhaust gases. The ECU **218** may also be configured to trigger the actuator **210** at other motorcycle speeds depending on the desired sound levels or noise emission characteristics of the engine.

Various aspects of the invention are set forth in the following claims.

We claim:

1. A method of operating a dynamic exhaust system of a motorcycle engine, the method comprising:

providing a valve in the exhaust system that is movable to direct exhaust gases between a first flow path through the exhaust system and a second flow path through the exhaust system, the first flow path yielding a first torque characteristic of the engine and the second flow path yielding a second torque characteristic of the engine;

actuating the valve at a first speed to redirect exhaust gases from the first flow path to the second flow path and to operate the engine at its second torque characteristic; and

actuating the valve at a second speed greater than the first speed to redirect exhaust gases from the second flow path to the first flow path and to operate the engine at its first torque characteristic, such that exhaust gases are directed through the first flow path at speeds both below the first speed and above the second speed.

2. The method of claim **1**, wherein actuating the valve includes one of opening and closing the valve.

3. The method of claim **1**, wherein actuating the valve occurs when the engine is operating at least about 75 percent of full throttle.

4. The method of claim **1**, wherein actuating the valve to redirect exhaust gases from the first flow path to the second flow path occurs at a first engine speed, and wherein actuating the valve to redirect exhaust gases from the second flow path to the first flow path occurs at a second engine speed greater than the first engine speed.

5. The method of claim **1**, wherein actuating the valve to redirect exhaust gases from the first flow path to the second flow path occurs at a first motorcycle speed, and wherein actuating the valve to redirect exhaust gases from the second flow path to the first flow path occurs at a second motorcycle speed greater than the first motorcycle speed.

6. The method of claim **1**, wherein actuating the valve to redirect exhaust gases from the first flow path to the second flow path occurs at one of a first engine speed and a first motorcycle speed, and wherein actuating the valve to redirect exhaust gases from the second flow path to the first flow path occurs at one of a second engine speed greater than the first engine speed and a second motorcycle speed greater than the first motorcycle speed.

7. The method of claim **1**, wherein actuating the valve to redirect exhaust gases from the first flow path to the second flow path occurs in a first crossover region of the first torque characteristic and the second torque characteristic, and wherein actuating the valve to redirect exhaust gases from the second flow path to the first flow path occurs in a second crossover region of the first torque characteristic and the second torque characteristic.

8. The method of claim **1**, wherein the actuation of the valve at the first speed to redirect exhaust gases from the first flow path to the second flow path and to operate the engine at its second torque characteristic occurs as speed is increasing from a speed below the first speed, and wherein the actuation of the valve at the second speed to redirect exhaust gases from the second flow path to the first flow path and to operate the engine at its first torque characteristic occurs as speed further increases from a speed above the first speed.

9. The method of claim **1**, further comprising triggering an actuator to actuate the valve.

10. The method of claim **9**, wherein an engine control unit triggers the actuator.

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